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APPLICATION OF JUST-IN-TIME PRODUCTION
METHODS IN THE DEFENSE INDUSTRIAL BASE

THESIS

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The views expressed in this thesis are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

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THESIS

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Master of Science in Systems Management

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Preface

The original idea behind this research effort came from a management accounting class required during my first quarter at AFIT. After reviewing the accounting procedures for several different types of production methodologies, I became curious about why all defense contractors were not using Just-In-Time. This curiosity eventually became "Why have some defense contractors adopted Just-In-Time?" Hence, my curiosity became the subject of this thesis research.

Actually finding firms that would participate in the research proved difficult at times. However, the people in the firms that did participate were all extremely helpful, cooperative, and genuinely interested in the subject of Just-In-Time. In fact, it became obvious on several occasions that these people were putting off more pressing matters to spend the time to talk with me. Although the promise of anonymity which was given to each of them precludes me from mentioning their names here, I owe a great debt of thanks to each and every one of them. Without their help, none of this would have been possible.

Beside the obvious help I received from Major Templin (for which I am eternally grateful), Drs Norman Ware and Guy Shane from AFIT provided a great deal of additional guidance on this effort. I am indebted all three of these people for both the time they spent with me and the opportunity to share some of their knowledge.

Finally, none of this would have been possible without the help of my father, John Anthony Cirello Sr. Thesis grade pending, hopefully he'll be able to read this and say "That's my boy!"

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Abstract

This study investigated the motivation for defense industrial base contractors to switch to Just-In-Time (JIT) production. Areas of interest included the original motivation for the contractor to change to JIT, how they implemented the change, which JIT methods they used, and what benefits they received from switching to JIT. A review of the current literature on the subject of JIT revealed that JIT is a philosophy of production based on inventory reduction, process improvement, and elimination of waste. This philosophy can be supported through the use of a number of different methods, and reductions in both cost and cycle time can result from the use of JIT. Information was collected through in-depth case studies of three firms from different industries representing each tier in the defense industrial base: supplier, subcontractor, and prime contractor. Competition was the common motivating factor influencing adoption of JIT among these firms. All three firms implemented JIT through the use of in-house resources, and none specifically identified their efforts with JIT. Supplier alliance programs were found to be the only common method used among the three firms. All three realized cost and cycle-time reductions as a result of switching to JIT.

APPLICATION OF JUST-IN-TIME PRODUCTION METHODS IN THE DEFENSE INDUSTRIAL BASE

I. Introduction

General Issue.

To support national security objectives, the United States Air Force (USAF) procures many different types of manufactured items such as weapon systems and spares. The cost of weapon systems alone has increased steadily over the years. According to then Senator Dan Quayle in 1984, as chairman of the Special Task Force on Selected Defense Procurement Matters for the Senate Armed Services Commission:

> I am concerned that we have not looked at the most fundamental and central questions that the [acquisition] system's operation raises. In 1951 the Department of Defense ordered 6,300 fighter planes at a cost of $7 billion (in 1983 dollars). This year we will spend $11 billion to build only 322 planes. I am fully aware of the fact that weapons systems today are hardly comparable with systems 30 years ago, but that does not change the reality of trends toward far higher unit costs and far smaller quantities, trends that must be of concern to anyone who cares about our national defense (Gansler, 1989:141).

With the present shrinking defense budget, the purchasing power of the Air Force is an important area for concern. Since procurement funds are in short supply, the Air Force will have to purchase fewer weapon systems if they are produced using the same traditional Western manufacturing practices as in the past. Alternately, the Air Force could find ways to increase contractor productivity by encouraging the use of different manufacturing methods. This will help offset the loss of purchasing power from a declining budget. In other words, we could find ways to purchase items at a lower cost.

Another important area of concern is the ability of defense contractors to produce weapon systems rapidly in response to a war -- our industrial bases's surge capacity. A report by the House Armed Services Committee in 1980 entitled "The Ailing Defense Industrial Base: Unready for Crisis" indicated that our industry's ability to produce weapon systems to support mobilization had severely degraded and jeopardized national security (Ninety-Sixth Congress, 1980:1-3). This was still an area of concern in 1985, when the Defense Financial and Investment Review indicated "the nature and health of the subcontractor industrial base is not well understood" (DOD, 1985:E-2).

Although our industrial base's surge capacity has been a on-going area for concern, little has been done to improve it. According to Dr Jacques Gansler, former Deputy Assistant of Defense for Materiel Acquisition:

> Historically, when emergencies have developed, there has been an absence of peacetime planning to meet these crises. Such efforts are usually postponed until the crisis occurs -- at which time it is too late. The result of the lack of industrial preparedness planning has been that in all its wars -- for the 200-year history of the United States -- the nation has been able to mobilize men much more rapidly than it has been able to equip them. Because of the increased sophistication of equipment today, the lead times are far longer. Thus, without proper planning, the response to a crisis today would be far slower in spite of America's overall industrial strength. In order to prepare, in peacetime, for a possible conventional conflict, the United States basically has two choices: to take actions and make the investments to have a responsive defense industry, or to stock enough military equipment to sustain a conflict for the several years it would take the defense industry to get up to speed (Gansler, 1989:241,266).

The likelihood of the Air Force being able to procure enough equipment to create a wartime reserve stockpile of weapons lessens with a declining defense budget. Therefore, we are left with the option of creating a more responsive defense industry by encouraging contractors to shorten lead times.

Specific Problem Addressed.

With a declining defense budget and the urgent need to increase our industrial surge capacity, the Air Force must take action in order to continue supporting national security objectives. We need to find ways to decrease the cost of weapon systems in light of a tighter defense budget, but at the same time it needs to find ways to shorten the production lead time for these weapon systems to remain ready for war. One possible solution to these simultaneous problems is to encourage contractors to use just-in-time (JIT) production. JIT is a philosophy of manufacturing whose implementation can not only reduce the cost of manufactured items, but at the same time can reduce the lead time required to manufacture those items.

Some United States (US) firms have already changed from traditional Western manufacturing philosophies to JIT. Some of these -- such as Honeywell, and Texas Instruments (Schonberger, 1986:232,235) -- are contractors to the Air Force. However, defense contractors in general have been slow to embrace the JIT philosophy. Schonberger's "Honor Roll" for JIT companies lists only four out of 84 firms as defense contractors (Schonberger, 1986:229-236; Besser and others, 1988:39). His "World Class Manufacturing Casebook: Implementing JIT and Total Quality Control (TQC)," has only two out of 24 cases involving defense contractors (Schonberger, 1987:1,18). A search of JIT-related case studies published in periodicals for the period January 1986 to

December 1990 revealed that only nine of the 81 firms mentioned were defense contractors (Pro Quest, 1990). In short, defense contractors appear to be slower than the rest of US industry in adopting JIT.

Obviously, firms in the defense industrial base that have already changed to JIT must have had some motivation to do so. If the Air Force wants to be able to encourage other firms to switch to JIT, the reasons why other firms have changed need to be understood. This information would be very useful to the development of an acquisition strategy aimed at encouraging JIT. For instance, the Air Force might want to try to duplicate (possibly through incentives) those factors which encouraged others to adopt JIT.

Research Questions.

The basic research question to be addressed here is "Why have firms in the defense industrial base changed to JIT?" However, in performing the research, there are several other questions which have to be answered. The first supporting question is "How has JIT been implemented by firms in the defense industrial base?" Although this seems trivial at first glance, it is actually very important to any Air Force strategy to encourage JIT. JIT is a philosophy of production, not a set of established procedures for production. Philosophies in general are open to interpretation by their advocates, and it is important to know how this philosophy has been interpreted by defense firms that have changed to JIT.

The second supporting question which must be answered is "What JIT methods are being used by firms in the defense industrial base?" The answer to this question is also important to the Air Force due to the nature of JIT. The JIT philosophy embodies a set of concepts, each of which can be implemented through the use of several different methods. Knowing what methods other firms have chosen is also important to the Air Force, since incentives could possibly be tied to the use of these methods as a way of encouraging contractors to switch to JIT. Finally, the third supporting question to be answered is "What benefits have been realized by firms in the defense industrial base as a result of their switching to JIT?" Again, this is important to the Air Force, since there must be some assurance that effort spent in encouraging contractors to switch to JIT will bring about the desired benefits.

" to answer these questions in a statistically correct manner would involve a prohibitively large effort, which is addressed in the methodology chapter. The answers sought by this effort are the "corporate" answers -- in-depth and detailed answers which a survey is unlikely to provide. Instead, answers to the general research questions were sought from three firms in the industrial base, and the specific questions which this effort answers are:

1. Why have these three firms changed to JIT?
2. How has JIT been implemented in these three firms?
3. What JIT methods are being used by these three firms?
4. What benefits have been realized by these three firms as a result of their switching to JIT?"

Significance of Research Effort.

A research effort such as this which aids the Air Force in encouraging contractors to switch to JIT supports current Department of Defense (DOD) guidance for systems acquisition. For instance, one of the objectives of DOD manufacturing management is to help provide for efficient and economical production of systems (DSMC, 1989:1-1). A production philosophy such as JIT, which reduces costs <u>and</u> shortens lead times, can be said to be both efficient <u>and</u> economical.

Also, DOD Directive 5000.1, Defense Acquisition, defines a primary responsibility of the Defense Acquisition Executive (DAE) as ensuring that each weapon system procured is manufactured in the most efficient, cost-effective, and highest quality method possible (DOD, 1991:28-29). Thus, JIT production of weapon systems should have interest at the highest levels of DOD. Finally, "the goals of Total Quality Management and Could Cost are to improve the quality and lower the cost of systems acquisitions," (DSMC, 1989:1-6) so the use of JIT in Air Force procurements would support existing DOD and USAF programs.

With regard to the subject of JIT, this effort examines an untouched area in current systems acquisition research. One research effort aimed at determining the benefits of JIT purchasing in a variety of commercial firms (Ansari and Modarress, 1987:31,35). Other efforts have validated the use of JIT tools to improve manufacturing performance over that attainable with other production philosophies (Krajewski and others, 1987:39,42; Sines, 1991:1-1). With regard to the defense environment, there has been research determining the effects of JIT on the worker's environment (Grant, 1990:iii), and on the effects of defense contracting practices on the efforts of firms attempting to adopt JIT (Templin, 1988:iii). The benefits of JIT and its adaptability to the defense systems acquisition environment are well-established in research. However, defense industrial base contractors have not adopted JIT as quickly as other segments of the US economy. Determining why some defense contractors <u>have</u> adopted JIT is an area of research that has not been addressed yet.

Scope of Research.

The research effort presented here is limited in several ways. For example, there is no effort to enumerate all concepts and methods associated with JIT. Since the JIT benefits of interest here are cost and cycle time reduction, the review of literature is limited to those JIT concepts and methods which have a direct effect on cost and cycle time. Other significant concepts and methods are not reviewed in the interest of being concise and brief. Furthermore, the review is restricted, where feasible, to US firms which have changed to JIT rather than those that began business by using JIT. However, since JIT is generally associated with Japanese manufacturing practices, some supporting information in the review of literature is related to foreign sources.

This effort is not, however, limited to prime contractors to the Air Force.

> "Of the many thousand companies that comprise the defense industrial base, the majority (over 70 percent) are classified as being subcontractors and lower tier suppliers. More than half of all the dollars expended for defense materiel acquisition go to this segment of the industry" (DSMC, 1989:2-5).

This distribution of dollars between prime contractors and lower tier contractors has been typical over the years. Between 40 and 60 percent of weapon systems cost went to subcontractors in 1968 according to the Senate Hearings on Competitive Defense Procurements in that year (Gansler, 1989:258,383). Therefore, by limiting the effort to prime contractors, the majority of the possible subjects would be excluded.

Also, any effort which aims at saving money for the Air Force should address the areas where the most money is spent.

Finally, the research effort is limited in its generalizability to the three firms selected for case study treatment. Since this is a new research area, the effort aims to gather in-depth information across each tier of the defense industrial base to guide future efforts by developing hypotheses concerning the motivation of firms switching to JIT.

Thesis Organization.

Chapter Two provides a review of literature on the subject of JIT. A brief history of the origins of JIT, along with information on the philosophy, concepts and methods associated with JIT are presented in this chapter. This information is followed by a review of the material available in literature which pertains to the research questions. Chapter Three details the reasons behind the selection of a case study treatment for this effort, why three firms were selected for case studies, and the methods used for gathering information during interviews.

Three case studies are presented in Chapter Four. These are listed as "The Supplier," "The Subcontractor," and "The Prime Contractor." Because of a promise of anonymity, the names subject firms and the people who participated in the interviews are not given. Finally, the information obtained during the case studies and from the review of literature are used to draw conclusions and answer the research questions.

II. Background

Organization.

This search and review examines existing literature pertaining to the subject of JIT production techniques. First, a brief history of the origins of JIT is presented to show why JIT came into being at all. Then, the philosophy behind JIT is examined to gain some insight into the goals of JIT, followed by the JIT concepts which support this philosophy.

The methods and practices commonly associated with JIT production concepts are then reviewed, with the basic thrust being not to enumerate all information on JIT, but merely establish its diversity. Finally, the benefits realized by JIT implementation and the reasons behind JIT implementation are examined.

Origins of JIT.

The productivity of American industry dominated the world in 1946. Today, though, few would argue that our manufacturing industries face tough competition today from overseas -- particularly from Japan (Hall, 1987:1). One of the factors responsible for the increase in Japanese productivity is the use of JIT. The term "Just In Time" is commonly used to describe a particular manufacturing philosophy in which raw materials arrive at a plant "just in time" to meet demand, and the Japanese are widely credited with developing JIT. However, the original application of JIT started with Henry Ford (Schonberger, 1986:7).

At Ford's Highland Park factory in 1914, and later at his River Rouge factory in 1921, Henry Ford developed JIT techniques for discrete goods manufacturing -- automobiles in particular. The River Rouge plant was able to produce Model T cars in a production cycle of four days. This four-day production cycle started with the processing of ore into steel (raw material for the automobile) at a steel mill located on the plant site and ended with a finished Model T rolling out of the plant (Schonberger, 1986:7).

The modern-day version of JIT was developed in Japan during the period 1949 through 1970, and it continues to develop today. One account of the origins of JIT credits its birth to the Japanese shipbuilding industry in the early 1960's. At that time, the steel-making industry in Japan had overexpanded. The industry had so much excess capacity that shipbuilders could get very fast delivery on their steel orders. Shipbuilders were thus able to drop their on-hand steel inventories from a one month supply down to about a three day supply. In other words, they were receiving their steel supplies "just in time" to match production (Schonberger, 1982:17).

A more popularly held belief is that JIT began with Taiichi Ohno and the Toyota Motor Company in the 1960's and early 1970's (Schonberger, 1982:3; Hall, 1983:22; Ansari and Modarress, 1987:20; Suzaki, 1987:147). This account holds that Toyota's inventory control system was the first large-scale application of JIT. The Toyota system, which is still in use today, is often called the kanban system. In fact, the terms "kanban" and "Just In Time" are often used interchangeably in manufacturing literature, even though this is not correct (Schonberger, 1982:3,17). JIT is a production philosophy, whereas kanban is a production control method which can be used to support JIT.

Why did JIT develop in Japan rather than another country? Well, after World War II, Japanese products had a reputation for poor quality. The reputation of their products was an embarrassment to the Japanese, and as a people they tend to take embarrassment seriously (Hall, 1987:49). Dr Edward Deming and others taught the Japanese principles of quality management in the late 1940s and 1950s, which may have precipitated the rise of JIT in Japan (Scherkenbach, 1986:9-23).

Also, Japan is a small country which is not rich in natural resources or space (being a small country). The JIT approach is well-suited to a country whose industries can not afford the waste of materials or factory floor space (Schonberger, 1982:3). Furthermore, they apparently realized that their livelihood depended on the ability to export low-cost, high-quality goods (Hall, 1983:48). For these reasons as well, it is not hard to believe that modern-day JIT techniques found their origin in Japan (Hall, 1987:49).

JIT Philosophy.

Inventory reduction. Part of the JIT philosophy can be found through a comparison of Japanese and traditional western manufacturing philosophies. Simply, Japanese industry produces small quantities of goods "just in time," while traditional western industries produce large quantities of goods "just in case" (JIC) (Schonberger, 1986:2-3). JIC production aims at keeping workers and machines fully utilized and prepared for emergencies. Also, JIC depends on having buffer stocks of raw materials and finished goods on-hand and ready for emergencies such as: machine malfunctions; fluctuations in demand; or fluctuations in supply. As a result of having buffer stocks to cover contingencies, a major manufacturing cost component is inventory (Willis and Suter, 1989:42).

JIT, on the other hand, places an emphasis on producing to the level of demand instead of overproducing for emergencies. The goal with respect to inventories is to have only the precise amount of material in the system that is required to meet scheduled demand (Willis and Suter, 1989:42). With less material in the factory, the carrying costs for inventory are less -- and thus costs are reduced. For example, the capital invested in materials alone for the majority of manufacturing companies is a high as 40 to 60 percent of total production costs, so reductions of even one percent in inventory can result in significant cost savings (Campbell, 1990:224). In addition to capital investment, holding costs such as floor space, insurance, taxes, and stock handlers are also reduced (Schonberger and Knod, 1991:332-334).

Process improvement. Another reason for reducing buffer inventory stocks is to expose problems in the production process. This also decreases cost. Problems in the production process can be poor processes creating defective parts, or simply slow machines creating bottlenecks in the production line. Defective parts and bottlenecks in the line increase production costs unnecessarily -- by increasing cycle time, for instance (Hall, 1983:11-16; Suzaki, 1987:16-17).

To illustrate this part of the JIT philosophy, a stream flowing over a bed of rocks is often used. Inventory in the production process is represented by the water in the stream, and the rocks represent process problems. While excess inventory hides these problems, lowering the level of inventory (water) exposes these problems (rocks) so that they can be identified and eliminated (Hall, 1983:11-16; Suzaki, 1987:16-17). This analogy is illustrated in Figure 1.

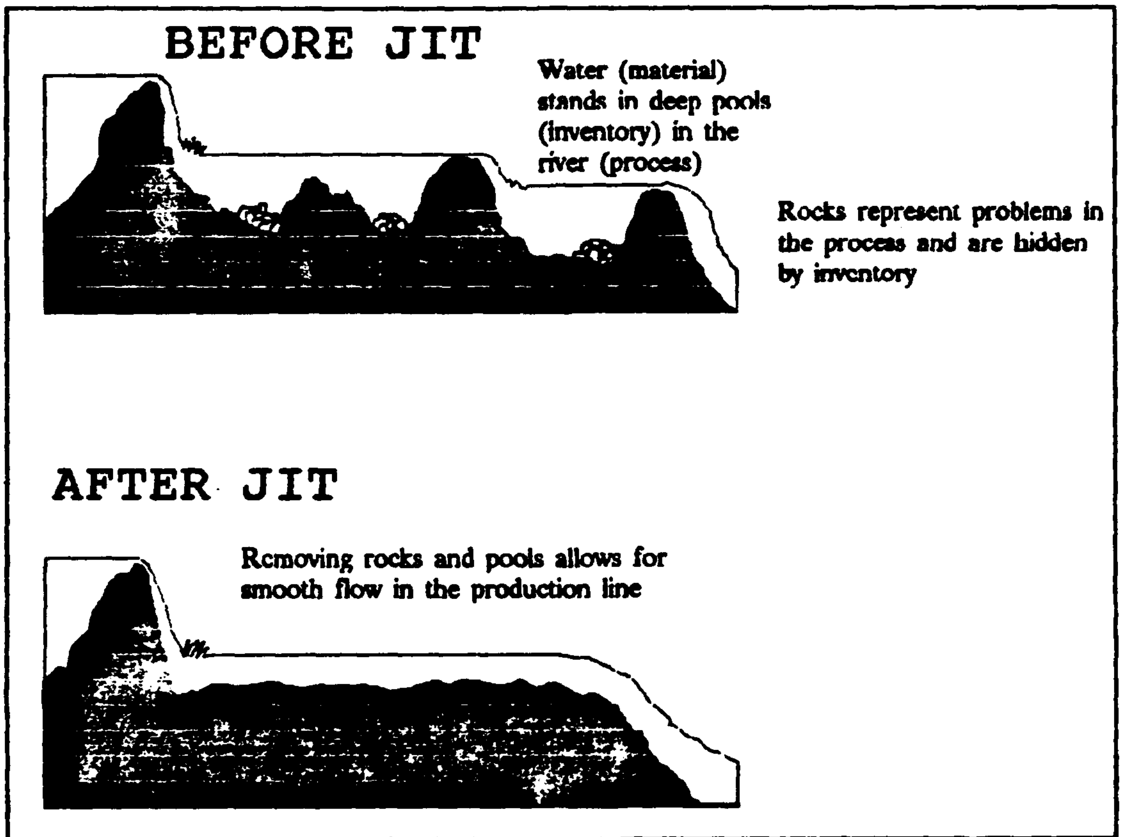

Figure 1. Water flow analogy (Hall, 1983:17)

Elimination of waste. Perhaps the most "all encompassing" part of the JIT philosophy is the elimination of waste. The seven wastes which JIT strives to eliminate were originally associated with the Toyota production system and have become fairly well recognized in their association with JIT (Shingo, 1986:16-17; Hall, 1987:26; Suzaki, 1987:12). They are:

1. Waste arising from overproducing: produce only what is needed now, stores of finished goods cost money to store.

2. Waste arising from time on hand (waiting): synchronize the production line so there are no "bottlenecks," workers waiting are paid without working.

3. Waste arising from transporting: unnecessary handling of materials adds cost to a product, but does not add value to the product.

4. Waste arising from processing itself: first question why this part or product should be made at all, then why each process is necessary, any unnecessary process increases the cost of a product unnecessarily.

5. Waste arising from unnecessary stock on hand: the cost of extra raw materials increases the overall cost of an operation, which increases the cost of the product.

6. Waste arising from unnecessary motion: wasted motion in a process increases costs because the process takes longer.

7. Waste arising from producing defective goods: defective products increase cost by wasting materials (Shingo, 1986:16-17; Hall, 1987:26).

The elimination of these wastes can be thought of as the basis for the JIT philosophy. Although inventory reduction and process improvement are key to the JIT philosophy, they can be traced back to one or more of the seven wastes to be eliminated.

JIT Concepts and Methods.

Now that the philosophy behind JIT has been established, the factory must be organized to support that philosophy. To describe the characteristics of a factory which engages in JIT manufacturing, it is important to define the terms used to describe those characteristics. The first of these terms is "manufacturing." Manufacturing is defined as all activity of a company that engages in production. "Production," on the other hand, is the actual conversion of material into finished product (Hall, 1987:2).

Two other terms which must be defined are "process" and "operation." A process is defined as the flow of products from one worker to another. In contrast, an "operation" is the specific, discrete step at which the worker performs the work. Production is therefore an network of processes made up of operations (Stickler, 1988:504-505).

Flexibility. The JIT philosophy is characterized by a set of underlying themes or concepts that are repeated consistently throughout literature: manufacturing excellence; continuous improvement; elimination of waste; flexibility; visibility; developing the productive potential of workers; uninterrupted flow; and process quality improvement. Flexibility, however, is the key concept in JIT manufacturing (Saint John, 1988:Sec 1,4-6; Hall, 1987:30-31; Schonberger, 1986: 2,205). Flexibility in relationship to JIT is used several ways, but primarily it means keeping the manufacturing process flexible in case the future (the market) does not occur as planned (Hall, 1987:30).

To illustrate this concept, imagine a factory which does not have a buffer stock of finished goods. Without excess finished goods on-hand, production must meet market demand or there will be shortages in finished goods - resulting in lost business with the customers. Since market demands for many products fluctuate with the seasons (i.e. the demand for children's toys is greater near Christmas), the output of a JIT manufacturing process must fluctuate as well. In other words, the production process must be flexible while remaining profitable (Sage, 1987:83,89).

The flexibility to survive variations in volume due to the market is an objective of JIT. A key component in this objective is the term "survive." To survive, a company must have their revenues exceed their expenses on a continuing basis. To accomplish this, the production process must operate without waste -- which is directly associated with excess costs. Eliminating waste reduces cost, and thus makes it easier for the firm to survive (Shingo, 1985:154).

Process organization. Another important concept of JIT manufacturing is found in the organization of the manufacturing operations on the factory floor. Pure JIT manufacturing operations are organized in a configuration called a "flow shop," whereas traditional manufacturing operations are organized in a configuration called the "job shop" (Hall, 1987:109).

According to Stickler, a job shop can be thought of as "scenic manufacturing," since the materials being processed take a "scenic tour" of the factory floor while moving from operation to operation (Stickler, 1988:504). Job shops have the following characteristics:

1. Machines normally fall into functional groupings.
2. Products are produced in a batch mode.
3. Work orders are used to track product costs.
4. The focus of manufacturing is on specific operations,
5. A considerable amount of transportation of materials is done.
6. Machine maintenance only occurs when there is a breakdown (Stickler, 1988:504).

In a job shop, the operations are compartmentalized, since the machines are organized on the factory floor by their function (such as all milling machines together). In a compartmentalized process, it is possible for materials to be transported hundreds or even thousands of feet while moving from one operation to another (Saint John, 1988:45). Figure 2 illustrates the advantage JIT has over a traditional job shop.

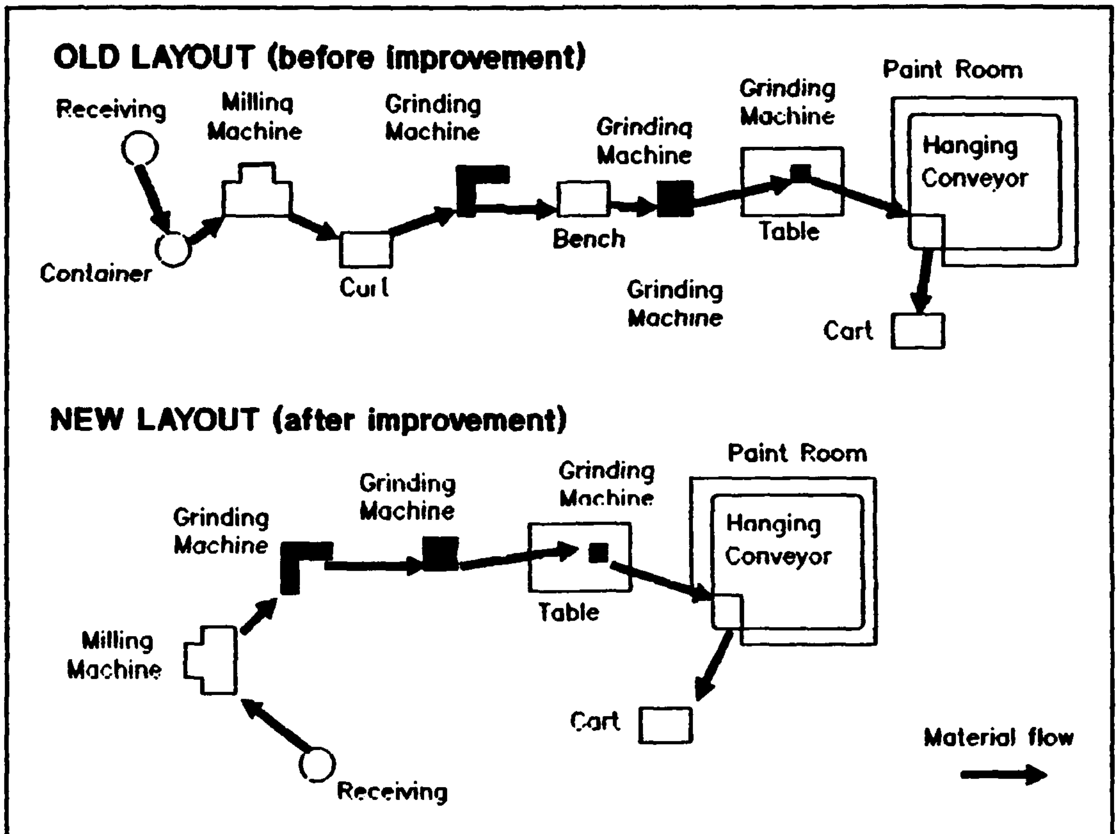

Figure 2. Production flow improvement (Suzaki, 1987:75,77)

One method used to organize the production process for a flow shop configuration is the use of visibility systems. Marked lanes or squares are used to define places for inventory, work in process, and operations (Potter, 1988:171). Also, by organizing the manufacturing line in a flow-type configuration, it is easier for workers to communicate problems with each other since the flow of materials is easier to see (Adair, 1988:29). JIT manufacturing requires organizing for quick product flow and tight process-to-process and operation-to-operation linkages. The overriding goal is to create responsibility centers where there were none before (Schonberger, 1986:102).

Traditional job shop manufacturing is the opposite extreme from JIT. In other words, the traditional job shop is not conducive to JIT manufacturing, since a process usually involves several operations. The distances between operations involve transportation, which is one of the wastes that JIT manufacturing tries to minimize. Organizations which cannot avoid job shop operation must strive to minimize the number of operations and distances between them (Schonberger, 1986:5-6,106-107).

The JIT flow shop configuration can be thought of as "expressway manufacturing," since materials flow through the factory floor with little deviation (Stickler, 1988:504). Some characteristics of flow shops are:

1. Machines are organized in a structured flow manner according to the process.
2. Lot sizes can be large or small.
3. Labor is reported in groups.
4. The focus of manufacturing is on the process rather than the operation.
5. Transportation of materials is minimized.
6. Machine maintenance and housekeeping is done by the operators (Stickler, 1988:504).

This method of organizing machines according to the manufacturing process is often called "functional integration" (Saint John, 1988:45) or "group technology" (Choi and Riggs, 1991:28). A conversion from a job shop to a group technology arrangement is illustrated in Figure 3.

With this method of organization, dissimilar machines are work stations are organized into a cell, commonly in a U-shape. By

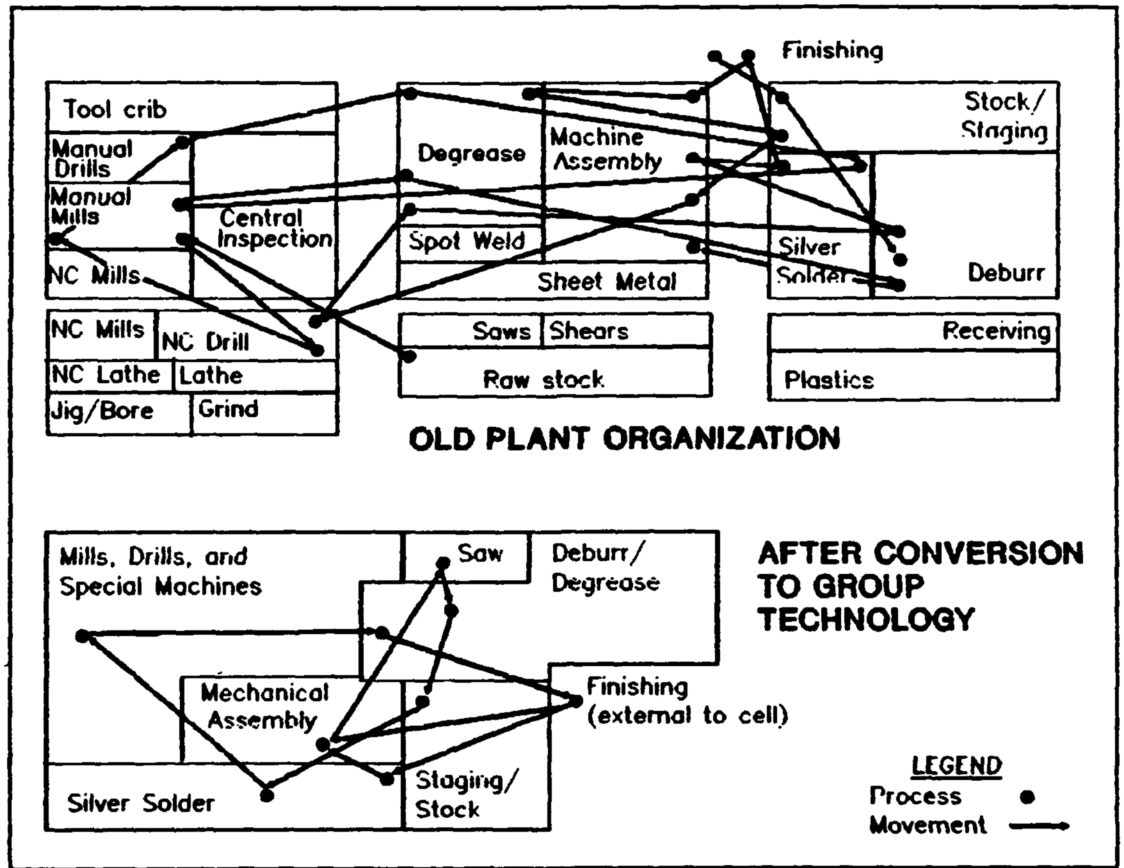

Figure 3. Conversion to group technology (Schonberger, 1986:113)

reorganizing from a strict "job shop" arrangement to a number of cells, waste due to transportation -- among other things -- is reduced (Goodrich, 1988:334).

While the job shop method focuses on improving only the single operation, the flow shop focuses on improving the entire process (Stickler, 1988:504-505). The benefits of a focus on the flow of the entire manufacturing process are: reduced floor space; shorter production cycle times; improvement in productivity and quality levels; reduction in total cost; and workforce involvement (Potter, 1988:171).

The JIT "flow shop" makes it possible to allocate indirect labor, energy, space (rent), and maintenance directly to the manufacturing cell

-- whether this is a group technology cell or a dedicated production line. These costs can be directly attributed to the product on basis of the production rate or another cost driver (Schonberger, 1986:374). Of the remaining indirect costs normally charged to overhead, many of them can now be charged as direct costs -- directly to the production process. Examples of indirect costs which could now (under JIT) be charged directly are: equipment depreciation, cell or process supervision, maintenance, utilities consumed, factory supplies (Montgomery, 1988:558).

Demand-pull system. A crucial characteristic of JIT manufacturing is the "demand-pull" system. In a pull-type system, material is pulled into final assembly from feeding operations as needed, one operation pulls material from the previous operation as needed, and the first operation in the line pulls material from stock as needed (Hall, 1987:91). If the process is set up like a pipeline with discrete cells or operations, and if the feeding operation has only one place to put material -- the pipeline -- then the feeding operation can only place material in the pipeline when an empty space appears. The only way an empty space appears is if finished product is removed from the other end of the pipeline (Hall, 1983:40).

In contrast, traditional manufacturing normally produces goods on a schedule. A schedule-based system such as a job shop produces finished goods on a schedule based on a estimate of the need. In other words, the manufacturing process works to fill finished goods inventory rather than to meet demand. The schedule pushes production, so this method is called a "push-type system." On the other hand, the pull system matches production with need, and the need is usually actual market demand (Schonberger, 1982:41).

A method used to implement a demand-pull system is the "kanban" system. The word "kanban" is a Japanese word meaning "card" or more literally "visible record" (Schonberger:17). The kanban card is a demand-pull tool that takes the place of production schedules in job shops. Kanbans can be cards, golf balls, labels, status boards, sequence tables, or even painted squares on the production floor (Suzaki, 1987:158,166,169,174,175). The kanban square, for instance, is the operation cell in the manufacturing process. The rules for use of the kanban square system are simple:

1. Don't start any work without an open kanban square.
2. Work to keep the kanban squares full.
3. Never pass on a known defect to another kanban square (Schorr, 1989: 60-61).

In a card-type system, there are typically two types of cards associated with a product -- a move card and a production card. A "move" card defines the path that a product must follow, and a "production" card defines the work to be done on that product. Typically, standardized containers are used to hold products, and the cards are attached to these containers. Also, a worker must come and get the materials needed from the previous operation, and he cannot move a container without a move card attached to it. Also, he cannot retrieve materials from the previous operation unless his work station is empty. In this manner, products cannot back up in the line and demand-pull is maintained (Hall, 1983:42-47; Suzaki, 1987:155-179).

The kanban arrangement, regardless of how it is implemented, is actually a production control system designed to reduce the waste of overproduction. There are also number of other different ways to implement this type of production control system. Among these are the use of a cycle table, which is used to balance the production in a mixed product line production operation. Also, the automotive industry uses a broadcast system, whereby information about completed manufactured items is communicated to the earlier stages of the production process (Suzaki, 1987:171-178).

Product data recording. Recording product and process data on the manufacturing line rather than during quality checks at the end of the line is another trait of JIT. For example, JIT production lines are often arranged in a "U" shape, where each part of the line is visible to each worker. In using a demand-pull method, shortages may occur where materials are demanded but not available from the previous work station. To make these problems easy to see and record, a system of green, yellow, and red lights at each station might be used to indicate either no problem, a work flow slow-down, or a work stoppage respectively. All workers on the line can see at which part of the line the light was turned on (Schonberger, 1986:20-23).

When either a yellow or red light is turned on, the reason for it being turned on is recorded on the spot. The results of these slow-downs or stoppages are periodically compiled and the workers take action to eliminate the causes. One possible cause might be that one worker has too much work to do, so his work is then redistributed somewhat to the workers before and after him in the line. This process of worker involvement is a method of "balancing the line," and ultimately it reduces the waste of waiting (Schonberger, 1986:20-23).

Value-added manufacturing. As mentioned earlier, the key to flexibility is the elimination of waste. JIT manufacturing focuses on "value-added manufacturing." The concept is simple: strive to eliminate activities that do nothing to add value to the product. The term "value-added manufacturing" is derived from the objective of elimination of waste, since waste is anything that does not add value to the product (Hall, 1987:23-24). The overriding goal of this process is to either reduce the product cost while retaining the original specifications or to increase the utility of the product while retaining the original cost (Hall, 1983:183).

Any manufacturing resource that is not actively involved in an operation that adds value is considered to be in a waste state. Therefore, waste includes all inventory that is not actually in being worked on (Sandras, 1988:274). Excess raw materials, or materials which do not arrive "just in time," are in a waste state. After work on a product has started, examples of activities which do not add value to the product are: unnecessary transportation of materials; unnecessary quality inspections of the product during the production process; or unnecessary storage of materials awaiting further work (Raeker, 1988:444-445).

Total quality control. The focus on eliminating unnecessary quality inspections is an important concept in JIT manufacturing. This doesn't mean that all quality inspections are eliminated, since another source of waste is creation of defective products. Instead, the focus is on "total quality control" (TQC). TQC may stand alone or may operate in concert with JIT production, but JIT manufacturing practices are frequently abbreviated JIT/TQC. The effects of TQC are "fewer rework labor hours" and "less material waste" (Schonberger, 1982:35-37).

Total quality control is implemented as a component of statistical process control (SPC). Before SPC, inspectors were in charge of quality by inspecting a random sample of finished products to cull defective products. JIT moves this responsibility downward in the factory hierarchy to the operators in the process cell. Taking measurements and plotting results on SPC charts at regular intervals means operators are involved in the product improvement effort all day long (Schonberger, 1986:37).

The JIT process exposes problems in quality, while the TQC process eliminates the causes of the problems. Production line workers use the data they record on the line to identify and eliminate the causes of quality problems (Sandras, 1988:275). The advantage of "on-the-line" inspection is clear from the philosophy that "time destroys the causes of quality problems." In other words, the more time that passes after a defect occurs, the harder it is to reveal the cause of the problem. By placing the quality control process at the worker level, the causes of quality problems are more readily cured. Also, a system of stockless production such as JIT will not work effectively without the elimination of scrap and rejects (Schonberger, 1986:137,150).

A common descriptive statistical method used in conjunction with TQC is the Pareto diagram. This is a simple classification of defects, customer complaints, or quality problems by category. The hypothesis behind the Pareto diagram is the Pareto rule -- 80 percent of the problems come from 20 percent of the sources. Therefore, the most productive way to attack defects is to attack the cause of the 80 percent (Hall, 1987:63).

Instead of focusing quality inspections on the finished product, quality inspections focus on the product in process (Schonberger, 1982:49). There are seven basic principles to TQC:

1. Process Control: checking the quality of the product during production.

2. Easy-to-See Quality: visual, obvious indicators of quality which are easy to understand.

3. Insistence on Compliance: making quality an overriding standard.

4. Line stop: giving the worker the authority to stop the line for quality problems.

5. Correcting one's own errors: elimination of a separate rework operation.

6. 100 percent check: inspection of every item, not just a random sample.

7. Project-by-project improvement: dedication to continuous improvement of quality (Schonberger, 1982:55-63).

In low volume operations, statistical control tools such as runs diagrams may be used. These diagrams consist of a measurement of every item in the production process. Fishbone charts, or cause-and-effect diagrams, may also be used to identify the causes of problems in a production process. In addition, scatter diagrams can be used to visually display the effects of proposed changes in a process with respect to the indicators of product quality (Schonberger and Knod, 1991:664-668).

JIT Benefits.

The following four items are stated benefits from existing literature which illustrate the benefits realized from JIT implementation. The industries mentioned -- aluminum, computer equipment, and ceramics -- are all industries which might be employed by the DOD in the manufacture of weapons systems.

1. Nippon Light Metal Company, a partner of Alcan Aluminum Company (US), implemented a "Toyota-like production system" in five plants over four years. Their total process leadtime reduction decreased from 10 weeks to 7 days. Over the five plants, they experienced productivity increases of 20% to 106%, inventory reductions of 50 to 90%, and manpower reductions of up to 39% (Child and Greenawalt, 1988:436,440).

2. Unisys Corporation, a manufacturer of computer equipment, in a two-year JIT process improvement effort, reduced manufacturing lead time for printed circuit boards from 10 to 2.4 days. Also, they reduced the direct labor hours required for fabrication by over 50% and reduced the backlog of boards which required rework from 58% of total production to less than 2% (Benoir and Jones, 1988: 476, 479).

3. In 1988, Digital Equipment Corporation upgraded a JIT effort to improve their operations which originally began in 1983. Their program, called a Cycle Time Reduction Program, reduced product cycle times by 60%. Similarly, work-in-process was reduced by 80% (Parmelee, 1989:598).

4. Corning, Inc., a manufacturer of specialty cellular ceramics, implemented a JIT system for process improvement in 1987. They realized a drop in defect rates from 1,800 parts per million to 9 and customer leadtime reduction from 5 weeks to as low as 30 hours as a result of this change (Sheridan, 1990:37,40).

Additionally, there are other stated advantages of JIT implementation which are not tied directly to an individual firm or industry, but are based on experience. Among these are the potential to reduce lead times by 50 - 75% (Hay, 1987:27). Other results of JIT implementation are: shorten production lead times; minimum inventory levels; and immediate reactive capability (Przybyla, 1988:518). Also, a study of Harris Corporation, Eastman Kodak, and Seagate resulted in the following observed advantages realized from JIT implementation:

production volumes increased 220%; lead time reductions of more than 60%; and inventory reduced by more than 58% (Bowman, 1990:332).

Reasons for JIT Implementation.

There are numerous examples in literature which mention reasons why firms adopt JIT practices. One of these uses Chrysler Corporation as an example. A key reason why Chrysler was able to avoid collapse in the early 1980's is credited to the use of JIT techniques to reduce inventory (Hall, 1987:16-17). The Chairman of the Board of Harley-Davidson, another company which has implemented JIT, states that the choice facing US manufacturers is to "become world competitive or become 'history'" (Beals, 1990:20). Toyota, a relatively famous JIT manufacturer, began expanding their JIT system to their suppliers, partly in response to the oil crisis of 1973, according to one account (Hannah, 1987:1). A common thread among these three examples of reasons for JIT implementation is the threat of extinction.

However, Omark Industries, which manufactures small-arms ammunition among other things, adopted JIT practices based largely on the encouragement of their corporate president and chief operations officer after he had made a visit to Nippondenso in Japan and observed their JIT operation. Although there was no threat of extinction, Omark's sales had stagnated in at least one area -- their sales to the lumber industry (Schonberger, 1987:31-32). Even so, a prime reason for JIT implementation seems to be the threat of extinction from competition, but not the only reason.

Since there is more than one reason a firm might be motivated to change to JIT production, these reasons could categorized into broad areas of motivation for change. A model presented by Luthans defines these categories. According to Luthans, the first category of motivation for organizational change can be a "highly competitive marketplace," which is roughly equivalent to the threat of extinction. The second category of motivation for change, though, is a tremendously accelerating rate of technological advance. A third reason for change is highly volatile changes in both the physical and social environment of the firm (Luthans, 1977:530).

Conclusions.

In addressing the supporting questions to the basic research question, some conclusions can be made concerning this review. The first of these is that JIT is a philosophy of production. This conclusion is supported by literature (Heard, 1987:50; Suzaki, 1987:6). The second conclusion which can be reached is that each of the concepts associated with the JIT philosophy can be implemented in a number of different ways. Again, there is agreement with this conclusion in literature (Sage, 1987:83-87; Bowman, 1990:332). There is no hard and fast methodology or set of techniques which can be called "Just In Time," Consequently, firms do not necessarily apply JIT in the same manner.

Another conclusion which can be reached here is that JIT can result in benefits which are valuable to the Air Force. One of these benefits is reductions in lead time to the customer -- either the Air Force in the case of a prime contractor, or a prime contractor in the case of a subcontractor or a supplier. Although there does not seem to be any conclusive answer as to how much of a reduction in lead time will result from the use of JIT, a general statement which is supported by this review is that the benefits can be significant. Further, benefits via cost savings can be significant as well through such improvements as reduction in defects and work in process.

Finally, there is not a consistent reason that firms switch to JIT production. Intense competition is one possible motivation for change. With regard to a change to JIT, this motivation is supported by literature, as in the examples of Chrysler and Harley-Davidson. Highly volatile changes in both the physical and social environment are another possible reason for organizational change. This is also supported in literature in the reasons for JIT developing in Japan.

However, another possible reason for organizational change (the change to JIT) is the high rate of technological advance. There would be little argument from anyone to the statement that Air Force weapon systems are technologically advanced, and that they advance at a rapid rate. According to Luthans, this could be a motivating factor for organizational change as well. Even so, the other two reasons in his model have been found to be factors contributing to changes to JIT, this reason is not found to be a cause in literature. The nature of Air Force weapon systems with regards to technological advance suggests that this should be a motivation for change to JIT.

III. Methodology

Introduction.

The purpose of this effort is to try and answer the basic research question: Why have three firms in the defense industrial base changed to JIT? The answer to this question is needed because JIT can provide the benefits of lower cost and shorter production lead times over traditional Western manufacturing philosophies. Some firms in the defense industrial base have already changed to JIT, but defense firms in general are slow to adopt JIT. Hence, the reasons that motivated some firms to change to JIT are useful information if the Air Force wants to encourage others to switch to JIT.

There are also three supporting research questions which help illuminate the basic research questions: How has JIT been implemented in these three firms?; What JIT methods are being used by these three firms?; and, What benefits have been realized by these three firms as a result of their switching to JIT? Regarding these and the basic research question, there is some information available in JIT literature concerning companies (not necessarily DOD contractors) who have already switched to JIT. This information has been summarized in Chapter Two. Here, justification for using a case study methodology to answer the research questions is presented.

Selection of Methodology.

Case study versus written survey. An important reason for the selection of a case study treatment rather than a written survey involves the terminology used by firms implementing JIT. To have a survey instrument which could cover all of the possible JIT tools and techniques and present all possible reasons for their implementation would require a rather large survey instrument. A large survey would be very likely to have a low response rate, since people might tend to ignore it because of the time it would take to complete. From past research, a sample of five defense contractors yielded 20 different tools being implemented to some degree (Templin, 1988:123). This shows that there is evidence from past efforts that a large sample of the defense industrial base will require a large number of tools to be included in the survey.

An alternative which would decrease the size of the survey would be to allow the subjects to fill in their own responses if none of the presented choices were appropriate. However, although this would decrease the size of the survey, it would add two confounds to the thesis construct. The first of these confounds would be the probability of unmanageable data scatter, since in one question given to 100 subjects, there could easily be 20 different answers to compile. This leads to the second probable confound inherent in this approach: two answers may be worded differently by different subjects, but may in fact be referring to the same thing. Again, this would limit the accuracy of the survey.

Case study versus telephone survey. Another possible method which could be used to collect data would be the use of a telephone survey. However, this would involve calls to a large number of people -- and possibly each individual call could be of considerable duration. The long distance calls. Furthermore, it is much easier to communicate with people face-to-face, and direct observation of a production process is always preferrable to a description of the process over the phone.

Size of the population. A main problem here is that the sample population, which includes subcontractors and suppliers, is very large -- 3,000 suppliers alone in 1981 by one estimate (Gansler, 1989:254). The probability of a large amount of data scatter increases with the realization that there are many differences in the way business is conducted between the two levels of defense contractors (upper tier and lower tier). Some of these differences include basic industrial structures and survival challenges (Gansler, 1989:257). The possibility of collecting data which would be inconclusive increases in light of these circumstances. Also, since the literature review suggested that defense contractors are slower in adopting JIT than the private sector, random sampling of the population would result in data from a number of firms which have not adopted JIT yet. To eliminate this data would involve a preliminary survey (asking questions about which methods are being used, for instance) to establish which firms should be included in the survey investigating the main research question. A two-survey research methodology would be too time-prohibitive for this effort.

Approach.

The primary method of data collection is through case studies of three firms: a prime contractor; a subcontractor; and a supplier. The case study methodology provides an effective avenue for reaching behind jargon, misconceptions, and "prepared" answers to find the real reasons for switching to JIT and assessments of the benefits and use of JIT tools. Three firms were chosen, rather than some other number, so that one firm from each tier of the defense industrial base was investigated. The chosen model for the defense industrial base is that presented by Gansler in 1989. Figure 4 illustrates this model and shows

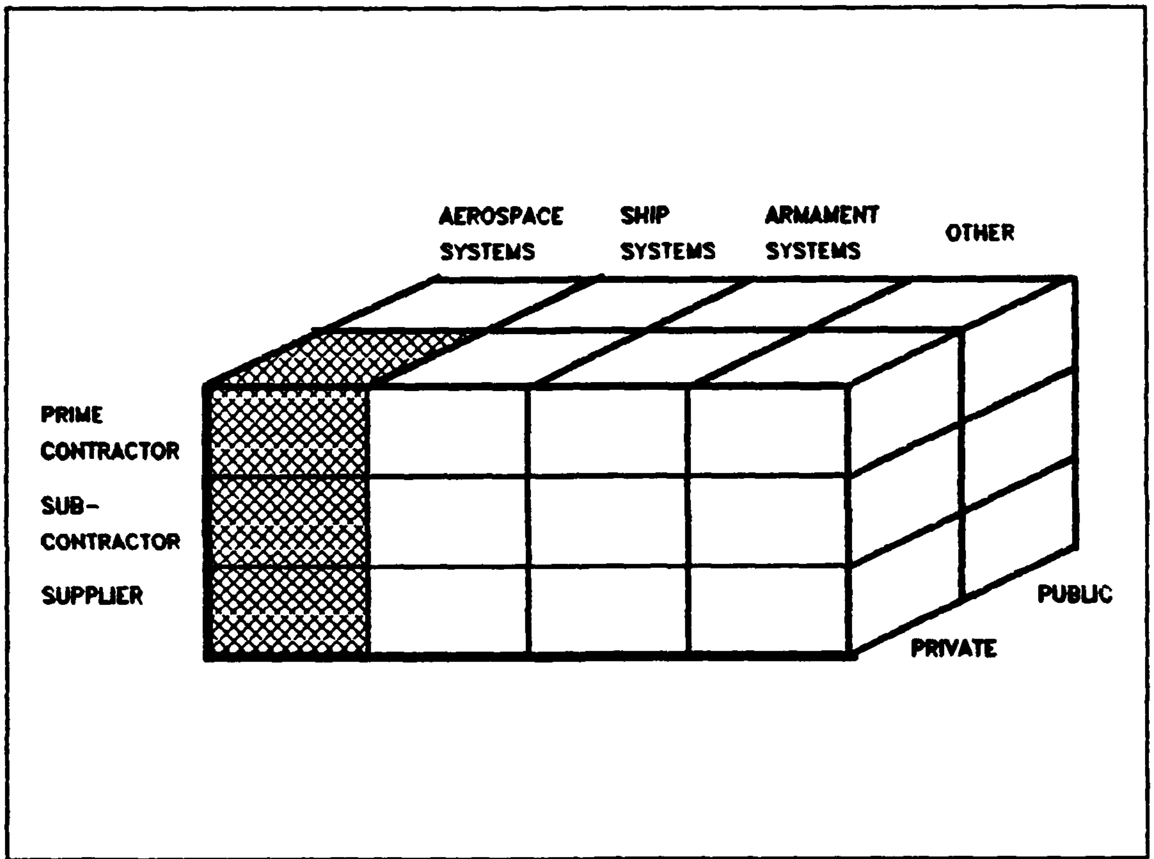

Figure 4. The defense industrial base (Gansler, 1989:240)

which portion of the defense industrial base is being investigated. From the data received by looking at the defense industrial base at a cross-sectional view, perhaps a hypothesis can be formulated for more rigorous statistical testing.

Procedure.

The primary method used in performing the case studies was through personal interviews. This helps alleviate misconceptions caused by a mismatch in terminology between the interviewer and the interviewee. Telephone interviews were used on occasion, and only when additional information was needed on a subject that was discussed during a personal interview. Also, company policy letters and news letters were used when to show progress of current programs and the policy statements of corporate management, when necessary.

Interview style. During these interviews, the objective of the research effort was not disguised. The subjects were told that the purpose of the interview is to determine: why their firm has chosen to change to JIT; how they implemented JIT in their firm; what JIT methods and practices they are using; and what benefits their firm realized from adopting JIT. They were also told that the purpose of the research effort was to complete a master's degree thesis and to gather information for the Air Force.

A strong emphasis was placed on obtaining the appropriate people in each organization for interviews. Efforts were concentrated on securing at least one person from each level of management, and interviewees were encouraged to involve other people in the organization whenever this could shed light on an area. This approach was successful in all but the largest firm visited (Case Three). Here, policy letters, company news letters, and program documentation were relied on to gain insight to the opinions of top management. However, through multiple interviews including people with different perspectives in each organization, a picture of what motivated each organization to change to JIT was obtained.

To support this type of interview style, a semi-structured interview method was used. This helped gain detailed information on specific subjects of interest to the research. An open, two-way discussion will be sought and obtained from each of the interviewees, rather than having to rely on asking leading questions. Each person interviewed talked open and frankly about his or her area of expertise. When needed, specific questions were asked during the discussion such as: "Why did you choose that particular method?"; "Did you try anything else first?"; or "Where did you learn how to do that?"

Each of the subjects were given the option of having the conversation recorded so that a transcript could be made later. However, all of the people interviewed declined in lieu of having the interviewer take notes. Interviews were held in the participant's office, and in some cases the conversation was continued during a tour of the production floor.

Survey Procedure.

The following procedure was followed during each interview:

Introduction. The interviewee was told that this is research on the area of JIT, since this is an area of concern for the Air Force. Each person was given a brief overview of the Air Force's need for this information and was also told who else in the company had already participated in interviews (if applicable). Each interviewee was also be told that he has complete anonymity both for himself and his company.

Discussion. Several direct questions were asked of all participants:

1. Why do you feel your company chose to switch to JIT?
2. What JIT methods are you using now?
3. What improvements or successes did you have from JIT?
4. Where do you think the initial idea to switch to JIT came from?
5. How did you learn about JIT?
6. How are you measuring your success?
7. Does your management support your JIT efforts?

Questions 1 and 4 are aimed directly at the basic research question: Why has their firm changed to JIT? Questions 5 and 7 are also aimed at the basic research question, but in a less direct fashion. Questions 2, 3, and 6 are aimed at the supporting research questions: how did they implement JIT; what methods are they employing; and what benefits did they realize?

During the discussion, follow-up questions were asked based on the responses to the direct questions in an attempt to stimulate the conversation. The purpose behind this is two-fold: to obtain more detailed information about specific topics of interest which might be offered during the discussion; and to obtain an answer about the possibility of competition prompting the switch to JIT. The latter purpose is important to the ability to maintain an open discussion. Since the subject of competition may also include the idea of company survival, this may bring about feelings of anxiety to the interviewee. Thus, tact and the need for honest answers precluded asking this question directly.

IV. Findings

Introduction.

The information presented in this chapter was obtained from personal interviews, telephone interviews, and releasable company documents. As mentioned in Chapter 3, the anonymity of each of the firms and the participants are preserved here. Also, trademark or distinguishing terms and descriptions of the actual product manufactured by each firm are also not mentioned here. The actual information obtained -- company and participant names, types of products, and other distinguishing terms -- were checked by the thesis committee.

Case One: The Supplier.

Profile. The parent corporation for this firm is a multinational organization composed of six Divisions and employing over 24,000 people total in the US. The firm, a raw materials supplier, is part of the Advanced Materials Division of the corporation and employs 1,800 people -- all in the US. Among other achievements, this firm was recognized for a "Supplier Excellence Award" by a major defense contractor in 1988, although this firm does no direct DOD business. Furthermore, this firm also supplies raw materials to a number of other companies whose products are used by the DOD.

This firm uses process-oriented production to manufacture its final product. The final product is a raw material for its customers, who further process it into a finished good. The different categories of final products this firm sells are all manufactured using essentially the same process. The primary difference between the different categories of products are their color and additives included in their manufacture. All products are made for the commercial market and some are used by DOD contractors.

This firm is composed of a headquarters and three production facilities. The locations visited for this case study were the headquarters and one of the production facilities -- their smallest. Contributing to the information in this case study, from the headquarters, were the Vice President/General Manager and the Quality Manager. From the production facility, the Operations Superintendent, Quality Manager, Production Engineer, and Scheduler contributed to the case study.

Motivation for JIT. The production facility visited was created primarily for the purpose of meeting the demand of customers using either JIT or other methods requiring small volumes and short lead times. Order patterns, which have been tracked continuously in this firm, were examined by the headquarters. They found that a trend had developed in which the orders they received were decreasing in size and increasing in frequency. The two other production facilities in this firm are designed to produce large volume lots of product. By their design, they cannot produce small, short lead time lots conveniently.

Also, the firm recognized that there was a desirable market for customers requiring small volume, one-of-a-kind orders. This production facility can easily accommodate this type of production -- whereas the other two facilities cannot. Thus, the trend that this firm responded to was a change in their customer's requirements with respect to order size, frequency, and diversity.

Another motivating factor, though not as important as the customer requirements, deals with the costs associated with doing business in the JIT environment. Their customers want smaller quantities of material delivered more frequently than before. However, it is difficult to respond to a short-suspense order on the west coast, for instance, when all production facilities are in the eastern half of the country. Therefore, consignment warehouses were established at selected customer's plants, with the cost of the warehouse being absorbed by this firm. The customer pays for the materials as he removes them from the warehouse, which allows the customer to maintain his "zero inventory" practices. However, this also increases the cost to the supplier. In fact, total support costs (which include consignment warehouses) are actually higher than material costs in most cases. Thus, cost reduction is another factor motivating some of the practices being used by this firm.

Implementation of JIT. The firm's implementation of JIT was accomplished largely through its own personnel rather than through outside consultants. Professional personnel were trained through short courses and seminars, such as those of the American Production and Inventory Control Society (APICS), or through their own studies of JIT literature. The expertise that they brought to the firm was incorporated into training programs which are tailored to the firm. Also, production line operators are currently being trained to perform some of the product quality inspections normally done by the quality laboratory. In fact, the great majority of new ideas to reduce cost or cycle time have come from production line operators or first-line supervisors.

One important observation that was made during the interviews is that although there is complete support for all JIT-related efforts underway in the firm, there is not active support for these efforts from the management of the Advanced Materials Division -- not to the detriment of the company, though. The next level of management above the headquarters is primarily concerned with cash flow. In other words, as long as the cash position is stable, there is no concern expressed from above. Efforts such as JIT-related improvements are neither discouraged nor encouraged from above, and they are only reported to upper management when they have a bearing on the concerns of top management.

JIT methods. The primary method found in use at this firm is multiple units of small capacity rather than fewer units capable of producing larger lots of material. The process used to produce final products remains essentially unchanged regardless of the size of the lot produced. By reducing the capacity of the production lines and increasing their number, the firm can more easily respond to the delivery requirements of their customers. In illustrating the entire production process, Figure 5 shows where these multiple production lines fit in.

Orders are placed with the headquarters, and these orders are then relayed to the appropriate production facility. Usually, a ship date of six weeks is given to the customer. The order is then scheduled at the production facility using a Materials Requirement Planning (MRP) system and the expertise of the scheduler. Open capacity is left in each of the 12 production lines, and orders are scheduled on the lines in such a manner as to avoid machine disassembly and cleaning (each of the lines

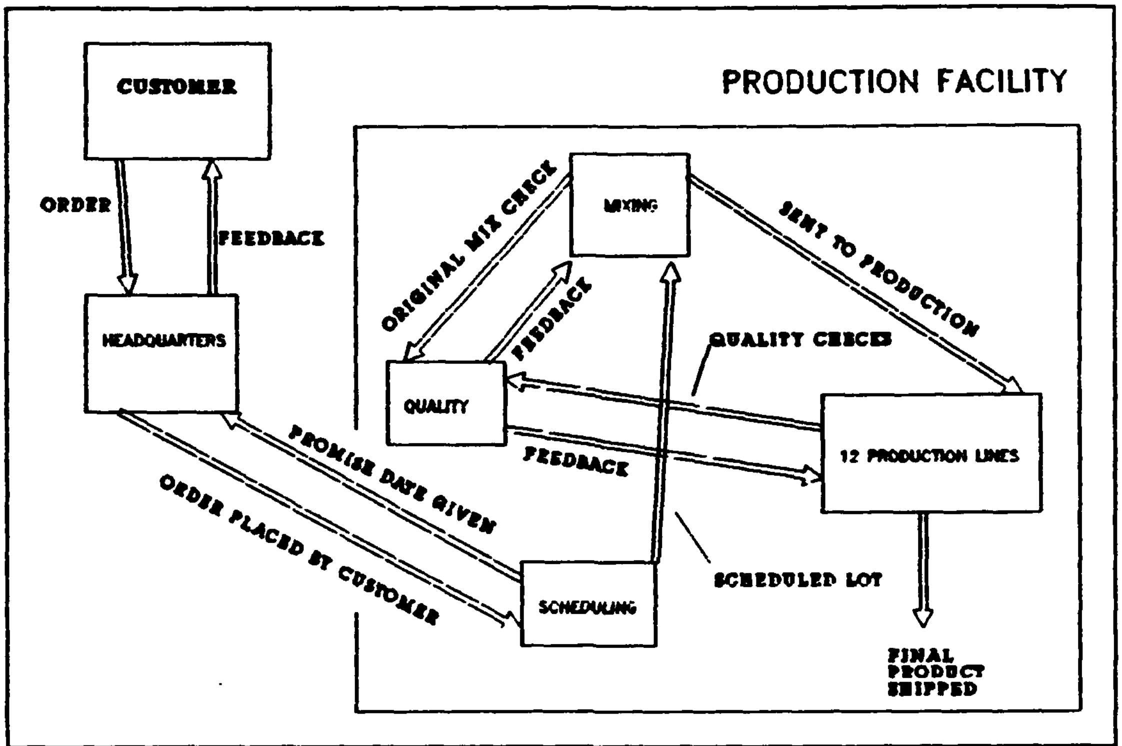

Figure 5. Supplier production process

experiences down time of up to 45 percent due to disassembly and cleaning).

Once an order is ready to be processed, materials are mixed and a sample is taken to the quality laboratory for processing and inspection. Once the mix is verified as meeting quality standards, the materials are committed to one of the production lines. The production lines are largely automatic, and little can be done to increase throughput other than to increase the size of the machine.

As mentioned earlier, the majority of new ideas to reduce cost and cycle time come from production line operators and first line supervisors. Although this suggests small-group improvement activities, this was not actually stated to be the case. However, another method which is in the process of being used is that some of the quality inspections are being assumed by production line operators rather than the quality lab. This reduces cycle time for the product, since the performance of simple inspections no longer requires the line to be stopped.

The primary JIT characteristics, then, are multiple units of small capacity and moving some quality inspections from the lab to the production floor. The firm has entered into strategic alliances with its suppliers in an effort to improve quality and customer service. Also, efforts are under way to modify quality testing to further improve the product's utility to the customer. For instance, dialogue with customers has resulted in modification and replacement of some of the quality assurance tests, which has in turn reduced the time required to test. Also, some of the mechanical properties tests have been modified to mimic the end use of the product -- further reducing the time required to test and increasing the product's utility.

JIT benefits. This company uses on-time delivery to the customer -- which has been tracked for many years -- as a measure of performance. On-time delivery is also a measure of the product's quality to the customer. In light of an new order patterns showing a tendency toward smaller, short lead time orders, this firm has been able to return a promise date to the customer which is shorter than the standard six week lead time 98 percent of the time. Furthermore, the firm has been able to deliver on or before the customer's request date 97 percent of the time.

With regard to reduction in cycle time, no specific figures were given indicating the magnitude of improvement. However, the combined information from the people interviewed firmly suggests that cycle time has been reduced. Also, the production firm was told recently to reduce their inventory of raw materials. They have been able to comply with this direction without affecting their operations or on-time delivery, which is another benefit of their JIT efforts.

Finally, the facility has been able to reduce costs as a result of their JIT-related efforts. This is the firm's most expensive facility, owing to the fact that all special-order products and new product development is done there. Even though no specific cost information was given, information was given clearly stating that, after an initial increase, costs have actually gone down.

Case Two: The Subcontractor.

Profile. The parent corporation for this firm is multinational organization composed of multiple divisions arranged along product and functional lines. Some of the divisions are involved in assembly of finished products, some are involved in fabrication of component assemblies, and some are self-contained (fabrication and assembly). The facility visited during this case study was involved only in fabrication of components, but it has been used as a testing ground for corporation-wide JIT initiatives. This facility employs approximately 250 people working on three shifts per day. Its end product is shipped to an assembly facility 11 miles away.

Manufacturing at the production facility is characterized by many different types of processes used in a job shop environment. The final products are made to specifications (size, shape, material, and features) reflecting their end-item use at the assembly facility. The firm's parent organization manufactures machinery which is often used in their customer's production facilities. These machines are manufactured primarily for commercial applications -- there is no specific line of DOD products. However, the parent corporation has an Aerospace Division, among others, and it has both subcontracted to DOD prime contractors and has sold capital equipment directly to Air Force Logistics Command. The plant manager and two of the operations supervisors at this assembly facility participated in interviews for this case study.

Motivation for JIT. The primary motivation for this company to adopt JIT was competition. The environment surrounding this decision was a situation in which many of their domestic competitors had been forced out of business by foreign competition -- both European and Japanese. The main impetus to convert to JIT was given by a corporate Vice President. In doing this, he initiated a program to reduce the cost of the facility's end product by 40 percent in 270 days. The managers of the facility chose JIT to accomplish this cost reduction.

Implementation of JIT. This firm's implementation of JIT was accomplished solely through the use of internal resources. In other words, the methods used were selected and implemented by the employees of the facility. First, a quality program was developed which was used to train their personnel in, among other things, the use of SPC tools. Next, a worker involvement program was developed to promote the adoption of cost and cycle time reducing measures as well as quality improvements. Both, the quality program and the worker involvement program were subsequently embraced and adopted by the parent corporation. Outside consultants did not play a significant role in the development or implementation of these programs. However, they were used to train personnel in the use of computer simulation tools used to analyze potential production floor reorganizations.

JIT methods. The primary JIT method being used by this facility was a reorganization of the plant floor to group technology cells. The plant floor was rearranged from a job shop to 17 manufacturing cells and a flexible (automated) manufacturing system. Computer simulation software has been used to periodically reevaluate the plant floor arrangement. Also, an effort to reduce the number of suppliers of raw material to the plant is currently underway.

An MRP-II system, tailored to the plant, is used to schedule orders on the plant floor. This system has been primarily developed by the employees of the firm, and its use is in its infancy as of the date of this research effort. Part of the challenge in implementing this system is that up to 40 percent of the orders which come to the plant (from the assembly facility) are "special order items." To assist in scheduling, production capacity is reserved in the production schedule, and a scheduling priority meeting is held among the managers every two days to integrate special orders into the existing schedule.

To reduce cycle time, machine set-ups have been converted from internal (requiring machine down time) to external (performed while the previous lot is still being processed). Workers perform preventative maintenance on the machines during their shifts, and the plant is shut down for two weeks each year for comprehensive maintenance of all machines. Visibility systems such as status boards are used on the production floor to keep workers informed about product quality improvements and cycle time reductions at various cells.

Also, the quality program, which consists of an initial six week training course followed by frequent updates, is used to train all production workers in the use of SPC tools. Furthermore, all employees are trained during this program in supplier-customer relationships. In other words, each worker is made aware that his customer is the next process, and managers are made aware that their customer is the workers themselves.

JIT benefits. Although there was no estimate given of the magnitude of the following benefits, the floor space required for production has been decreased and the firm's market share has increased. Evidence of the decrease in needed floor space was found during a tour of the plant, during which space which was formerly used for machining was found to be used for raw material storage in covered storage areas. Raw materials were previously stored outside the facility. Also, the cycle time to produce a finished product has decreased from 12 weeks to six weeks on average. Although no firm data was given as to the magnitude of the cost reduction realized, costs have reduced at least 40 percent for this firm's end product as a result of the corporate Vice President's initiative.

Case Three: The Prime Contractor.

Profile. The parent corporation for this firm is a US-based multinational organization. The firm itself is a prime contractor to the DOD, presently under contract to the Air Force and other services in DOD. This firm manufactures a complex product which is a major subsystem to many different DOD weapon systems and some commercial products. The firm's business is currently 60 percent commercial and 40 percent DOD. According to the people interviewed, the JIT-related efforts are applied to both commercial and DOD products. This firm has numerous facilities across the US, although only one of these facilities was visited.

Two high-level managers participated in the case study. Also, extensive use of internally-published (i.e. company news letters) material was used as the basis for some of the information and for further discussions with the participants. The size of the firm and government restrictions precluded obtaining detailed information on the processes involved, although a brief tour of the final assembly area was taken. However, enough information was obtained to provide answers to all of the research questions without actually observing the operations first-hand.

Motivation for JIT. The original motivation for this firm to adopt JIT practices came from the Chief Executive Officer (CEO) of the corporation. Upon assuming the CEO's position, he dictated to all divisions in the corporation that they must strive to reach "number one or two" status in their market or "he didn't want them" as part of the corporation. There was no firm reason given for the CEO's actions, but competition from other firms was at least one of the factors involved. From the CEO's direction, an initial goal of reducing inventory carrying costs was adopted by the firm. This gave rise to the JIT efforts in the firm. The path toward JIT production was then selected by the firm's upper management.

Implementation of JIT. JIT-related activities in this firm have been implemented almost entirely by positive management action. Programs which support the move toward JIT have been formed over the past three to ten years. For instance, one program is aimed toward facilitating small group improvement efforts. Another of these programs promotes and supports efforts to decrease cycle time. Each of these programs have been enthusiastically supported by the firm's top level management. News letters and company newspapers are used for the company Vice President (this firm's upper management) to convey support for the on-going programs, inform employees of the specific goals and initiatives of the programs, and relay to all employees the successes the company has realized from the programs.

An extensive restructuring of the organization was not required in this case to implement JIT -- the firm maintained their past structure during the change to JIT. The only change to the organizational structure is that every division in the firm now has a resident total quality advisor. Instead of reorganizing, action teams have been formed to bring about process improvements in specific target areas. Initial training for these teams is supplied by a consulting firm. The consultant provided the firm with a concentration is given on Deming's 14 points (Total Quality). From this basis, the JIT improvement activities are then internalized. In other words, the teams develop process improvements autonomously and then share them with the rest of the firm via a historical library.

JIT methods. The primary method used in JIT-related activities in this firm is the team approach to problem solving. In some cases, emphasis is given to reducing work-in-process for a particular segment of the operation. In other cases, emphasis is given toward reducing the number of parts in an assembly of the final product. The main thrust here is a team-oriented problem-solving environment, whose generalized solutions are shared with and adopted by the rest of the firm. There are currently over 500 teams working on specific items in the production process, and there are now 12 volumes in the solutions library.

Another method used is a dedicated program aimed toward improving supplier quality. An extensive effort has been undertaken to improve the relationship between the firm and the supplier. Technology and practices are shared between the firm and individual suppliers -- with both parties learning from the interchange. The supplier alliance program addresses such indicators of quality as: technology; financial and management aspects; delivery; and pricing. The primary goal is to develop a supplier/buyer relationship in which no product defects exist. Further, the number of major suppliers has been reduced from approximately 1400 to 900 in the past three years -- further adding to product quality conformance. Nonconformance of supplier products has been observed when suppliers are changed in spite of the specifications given.

JIT benefits. The benefits from JIT implementation which were estimated during interviews were a two-thirds reduction in cycle time and inventory carrying costs. Also, work-in-process on some specific parts has decreased more than 6-fold as a result of JIT implementation. In one particular subassembly unit, cycle time has been reduced from 29 to 13 days. Although no specific cost information was available (nor was it sought), cost and quality have increased significantly, since the firm's market share has grown steadily over the period of time that these practices have been adopted.

Other Information.

Of the three firms participating in this research study, none of them immediately identified their current efforts with JIT. Interviewees from all three asked questions at the start of the interview process to the effect of "What do you define as JIT?" Each firm had already developed their own programs with identifiable, trademark names. In fact, one firm associated JIT solely with raw material inventories, although they were actually using some JIT practices associated with JIT production.

Summary.

Table 1 is presented to summarize the actual information obtained during these three case studies. Marks are placed in each column to indicate only what is certain from the results of the interviews. This table is not intended to imply that there are not other categories which could be included. Also, the lack of an entry in one category for a firm does not mean that this company is not engaged in that particular practice. This table merely summarizes the firm, validated information that was obtained during the interviews.

TABLE 1

SUMMARY OF CASE STUDY INFORMATION

	Supplier	Subcontractor	Prime Contractor
MOTIVATION:			
Customer demand	■		
Cost reduction	■	■	
Competition		■	■
IMPLEMENTATION:			
Internal resources (employees)	■	■	■
Upper management support		■	■
Corporate programs		■	■
METHODS:			
Multiple units/small capacity	■		
Small-group improvement	■		■
On-line inspections	■		
Supplier programs	■	■	■
Group technology		■	
Visibility systems		■	
Set-up reductions		■	
BENEFITS:			
Cost reduction	■	■	■
Cycle time reduction	■	■	■
OTHER:			
Identification with term "JIT"			

V. Conclusions

Review.

The primary purpose of this research effort was to discover why three firms in the defense industrial base have switched to JIT. Also, the methods these three firms used in implementing JIT, the JIT tools that they are currently using, and the benefits they have realized since switching to JIT were important research questions. Current literature provides some preliminary answers to these questions.

For instance, a highly competitive market and drastic changes in the social environment were found to be reasons for other companies changing to JIT. Also, JIT is a philosophy of production whose concepts can be implemented through the use of a number of different production "tools." The benefits which result from JIT production -- cost and cycle time reduction -- are valuable to Air Force weapon systems acquisition. However, defense contractors have been slow to adopt JIT practices. Therefore, firms representing each tier of Gansler's model of the defense industrial base -- a supplier, a subcontractor, and a prime contractor -- were the subjects of case studies for this effort. The results of this investigation are documented below.

First Research Question.

The first research question was *Why have these three firms changed to JIT?* The supplier changed to JIT because of changing order patterns and the chance to service a new part of their market. They were not given direction or encouragement to change to JIT from their upper management. The subcontractor was given direction to reduce costs from their upper management, but the motivating factor behind this was competition from other firms. The prime contractor was also given direction from top management to improve their operation, but again the basis for this direction was competition from other firms. If the supplier's motivation is viewed in the light of maintaining their market share with respect to their competitors, then their motivation can also be thought of as competition-related. Thus, the common thread motivating these three firms was competition.

Although the supplier did not provide responses which indicated intense competition with other companies, the fact that they were adapting to changing customer order patterns and were attempting to service a new portion of their market indicate that their motivations were market-driven. The fact that the other two contractors adopted JIT because of competition also indicates that their motivations were driven by the market. Thus, all three firms changed to JIT due to market conditions.

This conclusion is consistent with the first category for organizational change presented by Luthans: a highly-competitive marketplace, and the threat of extinction (Luthans, 1977:530). This is also consistent with the reasons found in literature for other firms changing to JIT (Hall, 1987:16-17; Hannah, 1987:1; Beals, 1990:20). From this effort's in-depth examination of three firms, it can also be concluded that the reasons these firms changed to JIT are consistent with both JIT literature and one of the reasons for organizational change given by Luthans.

Second Research Question.

The second research question was How has JIT been implemented in these three firms? All three firms implemented JIT internally, through their own personnel. External organizations played a part in training the personnel of the supplier and the prime contractor in the uses of JIT tools. These training organizations were APICS and a consultant, respectively. The subcontractor's personnel did not receive any JIT training from outside sources, but did use a consultant to help install a software tool used to implement JIT in their facility.

Regardless, all three firms used the information provided by these external sources and then implemented JIT through the efforts of their own personnel. Thus, it can be concluded for these three firms that JIT implementation is accomplished using in-house personnel resources. Also, outside consulting can play a part in the implementation process, but not necessarily so.

There is no specific information available in current literature which bears this conclusion out. However, a finding which supports this conclusion out is the observation that all the firms had their own programs with trademark names to implement their JIT efforts. Furthermore, the observation that the term "Just-In-Time" elicited some confusion among the people interviewed supports the conclusion. Although each of these three firms were using methods and practices associated in literature with JIT, they were not familiar with a definition of JIT. This is probably due to their efforts being implemented using in-house resources -- the information about JIT was filtered through the internalization of the programs.

Third Research Question.

The third research question was What JIT methods are being used by these three firms? Only one common method was found between the three companies -- supplier programs. Other than supplier programs, there were no other methods used by all three firms. Referring to the summarized data in Table 1, this does not mean that small group improvement activities were used by the supplier and prime contractor and not the subcontractor. The subcontractor may in fact be using small group improvement activities even though they were not observed here. However, the conclusion here is that there is no unique set of methods used by firms in the defense industrial base.

This finding supports a conclusion of the literature review: JIT is a philosophy whose concepts can each be supported through the use of several different methods. Each of the firms investigated in this research effort had common goals of reducing cost and cycle time, yet each of the firms chose different methods to achieve their company goals. Also, each of these three firms from a different type of industry. Thus, it can be concluded for these three firms that the choice of JIT methods is either company or industry-dependent.

Fourth Research Question.

The fourth research question was What benefits have been realized by these three firms as a result of their switching to JIT? All three firms reported a cost-reduction motivation which was met by JIT adoption. The subcontractor and prime contractor reported significant reductions in cycle time. The supplier, although not reporting a reduction in cycle time, was able to meet the demands of a market which required shorter lead times for product manufacturing. Since there was no change in their process to meet these shorter lead times, the supplier also must have reduced his cycle time. Thus, it can be concluded that, for these three firms, JIT implementation results in cost and time savings. Again, this finding is supported by the review of literature.

Implications and Limitations.

In short, the results of this research effort are that, for three firms of the defense industrial base, JIT was implemented using in-house personnel in response to competition. Furthermore, there is no unique methodology being used by these three firms, and JIT implementation has resulted in cost and cycle time reductions. Also, where a comparison was possible between these three case studies and current literature, no difference was found between these three firms and those firms not in the defense industrial base. Even so, defense contractors are apparently slow to adopt JIT practices.

This implies that firms in the defense industrial base which have not yet adopted JIT are not subject to the same competitive pressures as these three firms were. However, this assertion is limited by several factors:

1. The generalizability of this effort is limited by the small sample size of three firms when compared to the large size of the defense industrial base population.

2. The three firms which participated in the case studies all have highly-developed commercial product lines. There was nothing in this research effort which yields information about contractors which do business solely with the DOD.

Regardless of these limitations, the common elements from the findings for these three firms (competition, internal implementation, and supplier alliance programs) supports the establishment of three hypothesis:

1. JIT adoption by defense contractors can be achieved by fostering competition for defense contracts.

2. JIT adoption by defense contractors can be achieved by encouraging contractors to use internal resources (personnel) to implement cost and cycle time reduction measures.

3. JIT adoption by defense contractors can be achieved by encouraging contractors to develop supplier alliance programs.

Also, an interesting comment which was made during one of the interviews that leads to the development of a fourth hypothesis. This comment was that the Industrial Modernization Incentives Program (IMIP) does not provide an incentive for reducing inventories. Since inventory reduction is a major tenet in the JIT philosophy, this may be a reason that some defense contractors have not adopted JIT. Thus, the fourth hypothesis developed by this effort is:

4. JIT adoption by defense contractors is hindered by the lack of incentives given by the DOD to reduce inventories.

It should be mentioned, though, that government factors such as the Federal Acquisition Regulation (FAR) were not found to either hinder or encourage the adoption of JIT by any of the three firms investigated. There is no support in the findings for this other than this comment.

<u>Contribution</u> <u>and</u> <u>Recommendations</u>.

This research contributes several things to present and past research. First, hypothesis have been developed based on in-depth studies of firms in the defense industrial base. These hypothesis, which are based on factual information obtained from the population of the defense industrial base, can now be tested via statistical sampling methods. Second, this effort shows that, in three more instances, the benefits of cost and cycle time reduction have been obtained through the adoption of JIT production methods. More importantly, though, other efforts such as those of Templin and Grant have concentrated on a single defense industry. This effort shows that the same benefits can be obtained in other industries as well, and in all three tiers of the defense industrial base. Finally, this effort has shown that not all firms in the defense industrial base may actually identify with JIT, even though they are using JIT tools. This may be important to future research which aims at surveying firms on the subject of JIT.

On the subject of future research, several recommendations can be made. Among these are:

1. Determining the possible effectiveness of an Air Force inventory policy in reducing cost or cycle time.

2. Determining the ability of the Air Force to encourage supplier alliance programs given the current Federal Acquisition Regulation (FAR) guidance.

3. Surveying defense contractors to determine their awareness of JIT with respect to philosophy, concept, and methods.

4. Testing one or more of the four hypothesis presented by this effort and their relationship to encouraging JIT adoption by defense contractors. Specifically, these are: increased competition; use of internal personnel to reduce cost and cycle time; supplier alliance programs; the IMIP program.

These efforts, if attempted, should strive to eliminate the limitations of this research. Specifically, the limitation of small sample size should be avoided. Also, an effort should be made to either determine the differences between firms with highly-developed commercial business and DOD-only firms, or to concentrate on only one of these type of firms.

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Vita

Captain Dominic J. Cirello was born on 13 October 1960 in Irvington, New Jersey. He graduated from Bishop High School in Bishop, Texas in 1978 and attended Texas A&M University. After transferring credits, he graduated magna cum laude from Fairleigh Dickinson University in Teaneck, New Jersey with a Bachelor of Science in Electrical Engineering (specialty: Computer Systems) in August 1985. Immediately after graduation, he attended and completed Officer Training School and received a reserve commission. His first duty station was Kirtland AFB, New Mexico. Originally assigned to the Air Force Weapons Laboratory, he began his career as Instrumentation Engineer in the Civil Engineering Research Division, and later assumed the position of Chief, Instrumentation Systems Section. During this period, he was involved in data collection for ground-based systems nuclear and conventional weapons survivability testing, and he was selected as Company Grade Officer of the Quarter for the period October through December 1986. He left the Weapons Laboratory for a position as Project Engineer, Satellite Technology Division, Air Force Space Technology Division in 1989. He remained at that position until assignment to the School of Systems and Logistics, Air Force Institute of Technology, in May 1990.

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13. ABSTRACT (*Maximum 200 words*)

This study investigated the motivation for defense industrial base contractors to switch to Just-In-Time (JIT) production. Areas of interest included the original motivation for the contractor to change to JIT, how they implemented the change, which JIT methods they used, and what benefits they received from switching to JIT. A review of the current literature on the subject of JIT revealed that JIT is a philosophy of production based on inventory reduction, process improvement, and elimination of waste. This philosophy can be supported through the use of a number of different methods, and reductions in both cost and cycle time can result from the use of JIT. Information was collected through in-depth case studies of three firms from different industries representing each tier in the defense industrial base: supplier, subcontractor, and prime contractor. Competition was the motivating factor influencing adoption of JIT among these firms. All three firms implemented JIT through the use of in-house resources, and none specifically identified their efforts with JIT. Supplier alliance programs were found to be the only common method used among the three firms. All three realized cost and cycle time reductions as a result of switching to JIT.

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